Price Indexes for Multi-Dwelling Properties in Sweden

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Abstract

The econometric test in this paper indicates that standard property and municipality attributes are important determinants of sales prices for multi-dwelling and commercial buildings (MDCBs) in Sweden. Spatial econometric techniques were used to determine that spatial specified regressions improved the models' explanatory power. The constant quality price for a model estimated with OLS is roughly one percentage point higher than for a model controlling for spatial autocorrelation. When the constant quality price trend is estimated on a yearly basis, there are hardly any differences between the estimated parameters, notwithstanding if all MDCBs are in the sample or if the sample is split into submarkets. However, estimating models with a quarterly constant quality price trend to some extent shows different price trends for the three submarkets.

Introduction

Accurate measures of the price trend are crucial for understanding the behavior of the real estate market. A substantial literature exists on the measurements of prices for non-standard assets, such as real estate.[1] Two major problems must be overcome in constructing this price index: the relative infrequency of sales of buildings and the heterogeneity in characteristics across building units. Simple price indexes based on mean prices of units sold in a certain period do not take into account the characteristics of the building sold. These indexes can thus not distinguish between movements in prices and changes in the composition of units sold from one period to the next.

The indexes compiled by Catella Property Management and Celexa Aberdeen Asset Management in Stockholm are examples of this type of simple price index for commercial real estate.[2] The price index for commercial real estate compiled by Statistics Sweden, which is based on an average of the ratio of sales prices to assessed value, has certain features similar to a constant quality index, since the assessed value reflects the market value of the house at a specific point in time. Still, the weights in the Statistics Sweden's index are not constant over time. Years with more or less sales in urban or rural areas will change the weights in the index and probably create a bias in the price trend, since the price level and the appreciation rates differ substantially between different areas in Sweden.[3]

The accurate measurement of housing and real estate price trends is thus crucial for understanding market behavior. For example, investigations on the ‘‘efficiency’’ of the housing market crucially depend on specific techniques generating the price indexes used for measuring the returns to arbitrage. Models, which investigate the determinants of speculative bubbles in real estate, also rely on the techniques for measuring prices. Real estate markets have also become more integrated with financial markets and the computation of housing prices has become of great practical importance to investors choosing between portfolios composed of real estate securities and other assets.

Constructing a price index for financial assets that trade frequently and regularly is normally a straightforward exercise. In contrast, infrequent trading and the heterogeneity of real estate require an entirely different methodology. The dominant approaches for constructing price indexes are hedonic models, the repeat sales method and the hybrid models combining the two above mentioned models. Hedonic models take into account the heterogeneity of the estate by incorporating the physical and locational characteristic of the traded units. Using the hedonic and the hybrid approaches makes it possible to extract the price trend for a constant-quality house. The repeat sales method only considers properties that have been sold at least twice. Thus, heterogeneity problems will be minimized since at least two transaction prices on the same property are observed.

Quite a few studies have analyzed the determinants of prices on owner-occupied houses in Sweden, using the hedonic and the hybrid approach.[4] Concerning other parts of the real estate sector, only one introductory study has been made for multi-dwelling buildings and commercial buildings (MDCBs).[5] This study concentrates on the price determinants for MDCBs with state-of-the-art techniques in econometrics.

This study had access to high quality data that enabled an estimation of constant quality price appreciation for different types of communities for the whole of Sweden. The property attribute variables were collected from the survey of the year 2000 for the General and Special Assessment of Real Estate. All variables in that database were thoroughly scrutinized by the tax authorities and other authorities involved, which is most likely a guarantee of the quality of data. Time series data was also pooled for a number of variables for Sweden’s 289 municipalities for every consecutive year between 1994 and 1998.

The econometric test, using spatial econometric methods, indicates that standard property and municipality attributes are important determinants for sales prices. A high degree of significant regional differences is also detected. In the empirical analysis, the findings indicate that interest subsidies to MDCBs are (almost) fully capitalized and rent control reduces the price per m^2 in some submarkets.

The estimated constant quality appreciation rates for MDCBs differ significantly from those reported by Statistics Sweden. This study works with pooled time series for a number of community attributes, which makes it possible to compute different price indexes for groups of municipalities. However, different methods of estimating the econometric model also result in different estimates of the rate of appreciation. The calculated constant quality price for a model estimated with OLS is roughly one percentage point higher than for a corresponding model that controls for spatial autocorrelation.

Results are also reported for quarterly constant quality price trends. A significant price trend for MDCBs with more than 75% dwellings can be identified from the third quarter of 1996 and onwards. The price trend for MDCBs with 25%–75% and less than 25% of dwellings, takes off a quarter later and lasts until the middle of 1998. Naturally, the difference in the price trend between the three categories of buildings is an indication that the three submarkets react differently to the economic upswings and downturns at the end of the 1990s.

The MDCB Market in Sweden—Stylized Facts

More than 120,000 units of MDCBs exist in Sweden and over 100,000 of these have been used for dwellings to a varying degree. About 60% of the total number of buildings consists of units where more than 75% of the premises are used for dwellings (Exhibit 1). The two remaining groups of MDCBs with 25% to 75% and less than 25% dwellings are evenly distributed. The difference between the total number of buildings and those used for dwellings is approximately 17,000. These 17,000 estates are vacant land, office premises, parking buildings, hotels

Exhibit 1 | Number of Units and Assessed Value for MDCBs

	Number of Units	Assessed Value (billion SEK)*
MDCB, total	123,084	945
The share of the premises used for dwellings in MDCBs		
More than 75% (320)	61,391	456
Between 75% and 25% (321)	23,441	207
Less than 25% (325)	21,363	222
Sub total	106,195	885

Notes:
*The average yearly exchange rate (year 2000) for $/SEK and €/SEK was 9.2 and 8.5, respectively.
Source: Statistiska Meddelanden, Bo 37 SM 0001, page 7. Statistics Sweden.

and restaurants. This study concentrates on the group of MDCBs with dwellings and excludes the last mentioned group of estates.

The assessed value of a real estate holding constitutes the tax base for taxing these properties. According to the tax law, the assessed value of the property should correspond to 75% of its market value (on average) two years before the taxation year. Every six years, all property in a certain category of real estate is subject to assessment. Between the taxation years, the model for calculating the assessed value is updated to reflect price changes in local property markets. In short, the model used to determine assessed value mainly uses rents, location, utilization and vintage of the property as determinants. These attributes are also used in the empirical analysis in this study.[6]

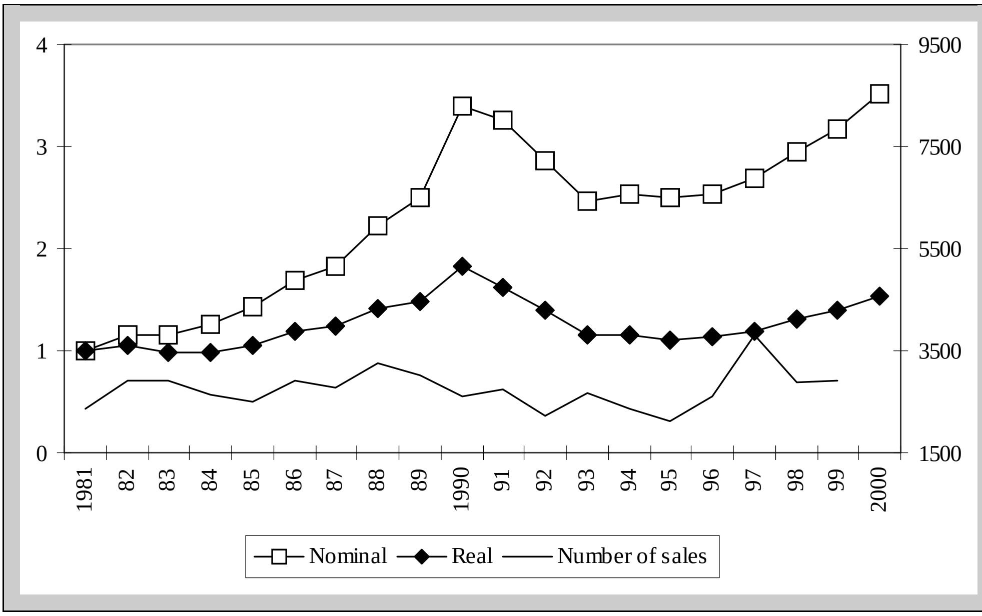
Exhibit 1 shows that the assessed value for MDCBs for the year 2000 amounts to approximately SEK 900 billion. This figure is also an estimate of the market value of these estates two years earlier. Correspondingly, the estimated market value of MDCBs for 1998 amounts to some 70% of Swedish GDP.

The reported sales are those where the titleholder changes; those where a corporation or partnership change owners are not available. Statistics Sweden supplied a time series in current prices for MDCBs since 1981. To obtain that price index, the reported sales prices are standardized by the assessed value for each property.[7] The price index in current prices and real price together with the average sales per year are displayed in Exhibit 2. The trend of the real price index has been worked out by dividing the nominal index by the consumer price index. The difference between the two prices (nominal and real) is thus linked to the general price trend in the economy. It is also possible to follow the number of sales in the same graph. The average value of the number of sales for the sample period is about 2,700 and the number of transactions fluctuates, obviously due to the business cycle. The average for the yearly turnover between 1995 and 1999 for MDCBs is SEK 25 billion, which gives a turnover rate of around 3%.

Between 1981 and 2000, the nominal price index for MDCBs increased by more than 13% (yearly average). From a peak in 1990, the prices fell back and stayed put during 1993–96. The slump at the beginning of the 1990s ended up in a more than 25% decrease (peak to trough). From 1996 and onwards, the price trend picked up again. Up to the beginning of the 1990s, the inflation rate was rather high in Sweden. As a consequence, the appreciation of real prices is far below the nominal price trend. The bust of the 1990s caused a fall in real prices of an astounding 40% (1990–95). During the second half of the 1990s, real prices started to pick up, but the real price level was still 18% below the peak level for the last observation in the sample.

Remember that aggregate numbers are being discussed. Studying more densely populated areas in Sweden gives another picture. For instance, Englund (1999) reports that the price increase for prime location commercial (non-residential) properties in Stockholm during the 1980s was much higher in the Stockholm area

Exhibit 2 | Trends in the Nominal and Real Price Levels



Note: Trends in the nominal and real price levels (logarithms and left-hand scale) and number of sales of MDCBs (320, 321 and 325) (right-hand scale), yearly data 1981 to 2000.

than elsewhere in Europe. According to the index used by Englund, prices slumped by over 50% between 1990 and 1993 in Stockholm, in nominal terms.[8] The boom to bust in real estate prices was most severe in the Stockholm area but there were significant price changes in all large cities during these years (*e.g.*, Jaffee, 1994).

The Hedonic Method and Spatial Econometrics

As has already been stressed, the dominant approaches used for constructing price indexes are hedonic models, the repeat sales method and hybrid models (combining the first two models). This paper uses the hedonic method. In the data set, approximately 350 units have been sold twice but the sample is too small to use the hybrid approach.

Hedonic models require extensive data sets, which should include transactions prices, the entire set of characteristics of each property and even a set of neighborhood characteristics. Naturally, obtaining all that data is not possible, so variables are normally missing when the models are specified and estimated. Recently, the method of controlling for spatial autocorrelation has gained growing popularity in applied statistical work since, in a way, this method copes with the problem of missing variables. One reason why house prices might be spatially autocorrelated is that property values in the same neighborhood capitalize shared location amenities for which data is normally not available. If spatial autocorrelation is present in a model, the resulting parameter estimates and confidence intervals will be inefficient.

Even if all necessary data is available, there are still problems with sample selection and the functional form of the hedonic model. Linear, multiplicative, semi-log, square root or Box-Cox transformed functional forms have been considered in the literature. This study experimented with different functional forms and tests favor the multiplicative or log-linear model, which is also used in the empirical work.[9]

A hedonic price equation is simply a relationship between property and community attributes and the market price of the property. Estimating a hedonic equation gives an estimate of the implicit price or valuation of each attribute. The relation between market price and attributes in Equation (1) is simplified as a multiplicative model as follows:

$$P = \alpha\left(\prod_{i=1}^{m} X_i^{\beta_i}\right) e^{\left(\sum_{j=m+1}^{n} \beta_j X_j + \sum_{t=1}^{T} \delta_t D_t\right)}, \tag{1}$$

where:

P = The price of the building;
X_i = The ith continuously measured attributes ($i = 1, \ldots, m$);
X_j = The jth attributes measured as ratio or binary ($j = m + 1, \ldots, n$); and
D_t = A dummy variable equal to 1 if the property sold during period t, and equal to 0 otherwise.

In specifying Equation (1), it is implicitly assumed that $\beta_1, \ldots, \beta_n$ are constant over time (*i.e.*, the relative market valuation does not change for the X_i and X_j attributes). Rewriting Equation (1) as a log-linear model and adding a property-specific random residual error term produces:

$$\ln P = \beta_0 + \sum_{i=1}^{m} \beta_i \ln X_i + \sum_{j=m+1}^{n} \beta_j X_j + \sum_{t=1}^{T} \delta_t D_t + \varepsilon. \tag{2}$$

If all attribute variables stay put over the estimation period, the constant quality price index, δ_t, can be derived from Equation (2). In the econometric work, however, eight attributes are used with changing values in each consecutive year—a pooled time series. To derive the price index, the changes in the eight attributes must be taken into account. The relative change in the constant price index for a certain period, t, vis-à-vis the benchmark year, 0, can be calculated for a certain region using, for instance, the average value of the municipality attributes, as:

$$\ln P_t - \ln P_0 = \sum_{k=1}^{8} \beta_k (\overline{X_k^t} - \overline{X_k^0}) + \delta_t. \tag{3}$$

If the β-parameters can be assumed to be constant over time, the constant quality index can be derived from the last equation and be used as an estimate of the rate of appreciation, without any loss of information. The use of pooled time series for the community attributes also makes it possible to compute different regional price indexes. The data set contains data for 289 communities in Sweden, so the index for different kinds of communities can be calculated and an example of such a calculation, with a certain number of regions, is presented later in this paper.

Spatial Autocorrelation

It has already been pointed out in the literature that if spatial autocorrelation is present in a model, the resulting parameter estimates and confidence intervals for these parameters will be inefficient. Using ordinary least squares to estimate transaction prices of real estate from multiple neighboring locations may produce biased and inconsistent parameter estimates. One reason for this phenomenon might be that houses in the same neighborhood capitalize shared location amenities for which data is normally not available. One solution to this problem is to set up a spatial autoregressive model.[10] This study follows LeSage and Pace (2002) who shows that a general spatial autoregressive model can be written as:

$$y = \rho W_1 y + X\beta + u, \quad u = \lambda W_2 u + \varepsilon \quad \text{and} \quad \varepsilon \approx N(0,\sigma^2 I_n), \tag{4}$$

where y is a vector with $n \times 1$ cross-sectional dependent variables and X represents a $n \times k$ matrix of independent variables.[11] W_1 and W_2 are known $n \times n$ spatial weight matrices telling what the influence of the neighboring observation is on the observation in question. ρ and λ are unknown autoregressive and autocorrelation parameters, respectively.

The econometric work in this study concentrates on two models: the spatial error model (SEM) and the spatial autoregressive model (SAR). The SEM model falls out from Equation (3), if assuming that $W_1 = 0$, *i.e.*,

$$y = X\beta + u, u = \lambda W_2 u + \varepsilon \quad \text{and} \quad \varepsilon \approx N(0,\sigma^2 I_n). \tag{5}$$

The SAR model is derived from Equation (4) if $W_2 = 0$, *i.e.*,

$$y = \rho W_1 y + X\beta + u, \quad \varepsilon \approx N(0,\sigma^2 I_n). \tag{6}$$

As can be seen from the last equation, neighboring properties influence the price of the subject property for the SAR model. This means that earlier prices and price indices are likewise related to the current price indices. The mixed regressive-spatial autoregressive model is also analogous to the lagged dependent variable model used for time series.

For the SEM model, the weight matrix is defined as a first-order contiguities matrix. To construct the contiguity weight matrices, the Delaunay routine is used which, in short, chooses some of the nearest surrounding neighbors, which means that different observations can have a different number of neighbors in the weight matrix.[12] For the SAR model, besides the specification of W_1 as a first-order contiguities matrix, a matrix specified from different numbers of nearest neighbors is also used.

In spatial econometrics, the estimation is carried out conditional on the chosen spatial weight matrix, therefore experiments with different econometric spatial specifications have been done. One approach examined one to three of the nearest neighbors as an alternative to constructing the weight matrix. The matrix with only one neighbor gave the best result in the econometric test, since adjusted R^2 did not improve for other specifications. However, this paper only deals with results for the SAR models where the Delaunay routine is used since these results are rather similar to those for the SAR model where the weight matrix is specified for different numbers of nearest neighbors. Naturally, there are many possibilities for experimentation with different model specifications in spatial econometrics. In this paper, a few specifications have been chosen.

This study explored whether interest-subsidized loans for MDCBs are fully reflected in the market prices. Interest-subsidized loans for apartment buildings and owner-occupied houses have been an import feature of the Swedish housing policy since the 1970s. A short account of the construction of these subsidies is given in the Appendix, together with a discussion of how the impact of these subsidies is modeled and empirically tested. The conclusions drawn from these tests are that subsidies are (almost) fully capitalized. Thus, this study concentrates on models specified either with or without subsidies. From here forward, the discussion concentrates on models where interest rate subsidies are not explicitly modeled; subsidies thus are included in the right-hand variable.

Data

The dataset from the National Land Survey of Sweden (NLSS) consists of high quality property attribute variables for the year 1998, collected for the tax assessment of the properties and includes variables such as rents for dwellings and other premises, space (m^2), utilization of space, the owners' own utilization of the premises, vintage and spatial coordinates for determining the geographical location of the building (Exhibit 3).[13]

Altogether, there are six property attributes in the data set, which is quite a small number as compared to many other studies. Note that there is a shortage of variables for the quality of the dwellings (*e.g.*, number of rooms, standard of kitchen and bathroom, fireplace in the flat, etc.). In an attempt to compensate for these missing quality attributes, the rent per m^2 for 1998 is used as a variable in the models. The reported rent for this year should, to a certain extent, reflect the quality of the flat since many other factors are controlled in the empirical models.

Concerning the variable ratio of rents from flats to the total income from rents, the hypothesis is that this variable might capture the effect of rent control. The non-profit public housing corporations by and large set the rents paid for dwellings. Due to special legislation, the non-profit public housing sector has a leading role in determining the general level of rents in accordance with their zero-profit constraint, thereby setting a cap on rents in privately owned dwellings. The rents for the part of the premises not used for dwellings in MDCBs are market determined.[14] The estimated parameter for this variable can be interpreted as an alternative cost for using a certain area of the premises for dwellings, and naturally, a negative sign is expected.

The sales prices for the properties are also collected by the NLSS, and the sample contains data from the second half of 1995 to the end of 1998. The number of observations used in the econometric work exceeds 8,500. The sample contains only properties with dwellings; vacant land, office premises, parking buildings, hotels and restaurants have been excluded.

Exhibit 4 shows the distribution of the logarithm of sales per m^2, the dependent variable in the models, is not entirely normally distributed; as indicated by the reported *p*-value for the Jarque-Bera test in the figure. The skewness of the distribution is also revealed by the fact that the median and mean values show different figures. The high value of the variable's standard deviation also implies that there is a long span between the minimum and maximum values, which are due to the geographical distribution of prices, since the mean value of the sales price in large cities is more than twice the price in rural areas (see Exhibit 3).

Quite a few neighborhood attributes or community variables are used in the empirical models and some basic statistics for these are displayed in Exhibit 3, together with the property attribute variables from NLSS. The variables in the table are stratified into four groups of municipalities. The empirical analysis began

Exhibit 3 | High Quality Property Attribute Variables for 1998

	Mean	Max.	Min.	Std. Dev.	Obs.
Panel A: Large Cities[a]					
1. Price per m^2	6761	31804	861	3566	1461
2. Rent per m^2	769	2750	70	193	1233
3. Ratio of rents from flats to the total income from rents	0.76	1.00	0.00	0.32	1461
4. Owners' relative utilization of the premises	0.17	1	0	0.35	1399
5. Ratio of vacant space	0.02	1	0	0.08	1399
6. Age of the building	41	69	1	20.8	1453
7. Distance to center, meters	3074	14970	113	2207	1461
8. Ratio of vacant flats in the area	0.01	0.07	0.00	0.01	1461
9. Tobin's Q	1.20	1.38	1.00	0.15	1461
10. Ratio higher to lower education	0.96	1.25	0.59	0.22	1461
11. Average income* 10^{-3}	206	230	182	16	1461
12. Ratio of total employees to those employees living in the area	1.36	1.43	1.27	0.07	1461
13. Ratio of net migration*	0.01	0.02	0.01	0.00	1461
14. Ratio of age group 20–29*	0.16	0.17	0.15	0.01	1461
15. Ratio of age group 50–64*	0.15	0.16	0.14	0.01	1461
16. Ratio of foreign subjects*	0.11	0.12	0.10	0.00	1461
17. Ratio of votes on non-Left parties	0.41	0.44	0.36	0.03	1461
Panel B: Large Municipalities[b]					
1. Price per m^2	4392	16953	400	1894	2578
2. Rent per m^2	673	8750	0	274	2358
3. Ratio of rents from flats to the total income from rents	0.79	1.00	0.00	0.35	2578
4. Owners' relative utilization of the premises	0.06	1	0	0.19	2454
5. Ratio of vacant space	0.04	1	0	0.12	2454
6. Age of the building	34	69	1	19.4	2578
7. Distance to center, meters	3734	56272	15	6247	2578
8. Ratio of vacant flats in the area	0.04	0.22	0.00	0.04	2524
9. Tobin's Q	0.83	1.10	0.49	0.11	2578

Exhibit 3 | (continued)

High Quality Property Attribute Variables for 1998

	Mean	Max.	Min.	Std. Dev.	Obs.
Panel B: Large Municipalities[b] (continued)					
10. Ratio higher to lower education	0.68	1.94	0.39	0.28	2578
11. Average income* 10^{-3}	217	246	188	11	2515
12. Ratio of total employees to those employees living in the area	1.06	1.21	0.91	0.06	2515
13. Ratio of net migration*	0.00	0.02	−0.01	0.00	2578
14. Ratio of age group 20–29*	0.15	0.21	0.11	0.02	2578
15. Ratio of age group 50–64*	0.17	0.19	0.14	0.01	2578
16. Ratio of foreign subjects*	0.05	0.11	0.02	0.02	2578
17. Ratio of votes on non-Left parties	0.39	0.48	0.28	0.05	2578
Panel C: Suburban, Industrial, Sparsely Populated and Small Municipalities[c]					
1. Price per m^2	3386	16556	271	2053	1949
2. Rent per m^2	618	3898	0	197	1627
3. Ratio of rents from flats to the total income from rents	0.66	1.00	0.00	0.39	1951
4. Owners' relative utilization of the premises	0.12	1	0	0.28	1837
5. Ratio of vacant space	0.06	1	0	0.16	1837
6. Age of the building	33	69	1	20.0	1950
7. Distance to center, meters	5634	131819	20	11585	1908
8. Ratio of vacant flats in the area	0.07	0.57	0.00	0.06	1797
9. Tobin's Q	0.72	2.30	0.32	0.32	1950
10. Ratio higher to lower education	0.50	2.63	0.22	0.34	1950
11. Average income* 10^{3}	234	414	187	30	1883
12. Ratio of total employees to those employees living in the area	0.93	2.08	0.31	0.29	1883
13. Ratio of net migration*	0.00	0.07	−0.03	0.01	1950
14. Ratio of age group 20–29*	0.12	0.17	0.08	0.02	1950
15. Ratio of age group 50–64*	0.17	0.23	0.14	0.01	1950
16. Ratio of foreign subjects*	0.05	0.26	0.01	0.03	1950
17. Ratio of votes on non-Left parties	0.43	0.83	0.12	0.12	1950

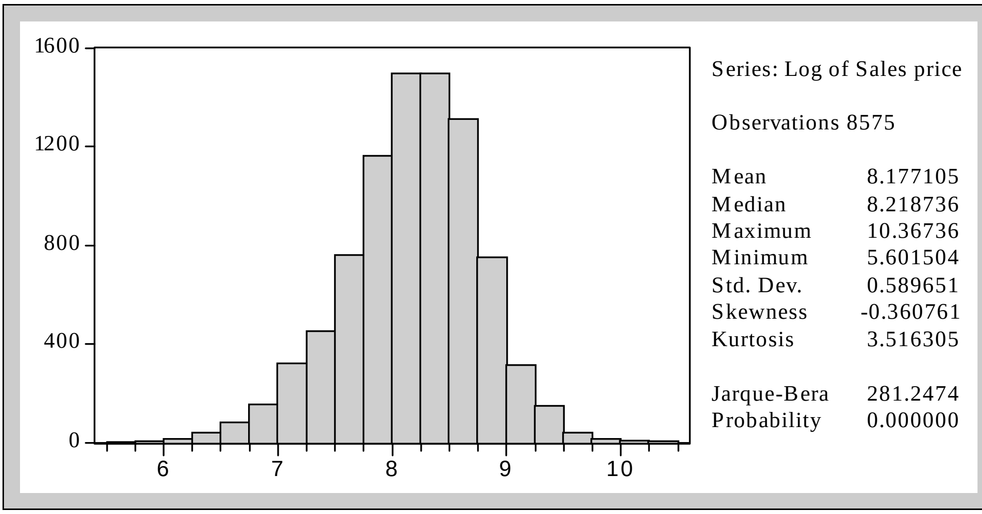
Exhibit 3 | (continued)

High Quality Property Attribute Variables for 1998

	Mean	Max.	Min.	Std. Dev.	Obs.
Panel D: Average Size Urban, Rural and Other Semi-large Municipalities[d]					
1. Price per m^2	3157	12409	348	1539	2587
2. Rent per m^2	607	1407	0	137	2230
3. Ratio of rents from flats to the total income from rents	0.73	1.00	0.00	0.37	2588
4. Owners' relative utilization of the premises	0.09	1	0	0.23	2414
5. Ratio of vacant space	0.06	1	0	0.16	2414
6. Age of the building	35	69	1	20.8	2587
7. Distance to center, meters	4582	110018	26	8108	2562
8. Ratio of vacant flats in the area	0.07	0.29	0.00	0.05	2527
9. Tobin's Q	0.68	1.11	0.37	0.14	2580
10. Ratio higher to lower education	0.43	0.72	0.23	0.09	2588
11. Average income* 10^3	221	269	180	13	2445
12. Ratio of total employees to those employees living in the area	0.94	1.44	0.47	0.11	2445
13. Ratio of net migration*	0.00	0.04	−0.02	0.01	2586
14. Ratio of age group 20–29*	0.12	0.17	0.08	0.01	2586
15. Ratio of age group 50–64*	0.17	0.20	0.14	0.01	2586
16. Ratio of foreign subjects*	0.04	0.10	0.01	0.02	2586
17. Ratio of votes on non-Left parties	0.40	0.72	0.14	0.09	2588

Notes:
[a] Stockholm, Gothenburg and Malmö—K1.
[b] Benchmark—K3.
[c] K2 + K5 + K7 + K9.
[d] K4 + K6 + K8.
*Divided by the total population.

Exhibit 4 | Logarithm of Sales Price/m² for MDCBs: 1995–1998



with nine different categories of municipalities but analysis determined that different types of categories could be joined for different samples of MDCBs.[15] The NLLS supplies the first seven variables in Exhibit 3, which are also property attributes. The numerical data for these property attributes variables is, as said earlier, entirely from 1998.

The rest of the variables come from other sources and they are classified as neighborhood or municipality attributes.[16] Each neighborhood is defined as a municipality and there are 289 municipalities in Sweden. Variables 8–15 in Exhibit 3 are pooled time series since they have values for every consecutive year. As already discussed, the use of pooled time series must be taken into account when the constant quality price is calculated (see Equation (3)). In the empirical tests, variables 8–15 in Exhibit 3 are also specified with a yearly lag in the models.

Exhibit 3 contains a considerable amount of numbers but it is easy to read. The numbers are those expected—the price per m² for MDCBs is highest in large cities etc. All the variables in Exhibit 3 are used in the empirical models and a short description of the variables is given in Exhibit 5.

Results

Hedonic models for different categories of MDCBs specified as OLS models and spatial autocorrelation models are tested. To restrict the number of models tested in the study, only the results from the OLS-specification and the spatial autoregressive models, SAR, where the Delaunay routine is used to construct the

Exhibit 5 | Independent Variables

		Description and Motivation	Excepted Effect
Panel A: Property Attributes			
2	Rent per m^2.	Proxy variable for the quality or the standard of the dwelling. Log specification. Positive elasticity is expected.	+
3	Ratio of rents from flats to the total income from rents.	Expect a negative effect due to rent control.	−
4	Owners' relative utilization of the premises.	A proxy for the degree of instant accessibility for the potential buyer. A positive effect on the dependent variable is expected.	+
5	Ratio of vacant space.	Vacant space in the premises might imply less rental income and thus, a negative effect.	−
6	Age of the building.	Log specification. Depreciation of the building—expected negative elasticity.	−
7	Distance to center, meters.	Log specification. Buildings far from the city center are expected to be cheaper than those near the center—expect negative elasticity.	−
Panel B: Municipality Attributes			
8	Ratio of vacant flats in the public housing sector.	Proxy for the demand for shelters—expected negative effect.	−
9	Tobin's Q (for owner-occupied houses).	In most cases, a high Tobin's Q indicates high demand for housing which should be correlated with the demand for dwellings—expected positive effect.	+
10	Ratio of higher to lower education.	People with three or more years in at least upper secondary school to those with fewer years. Higher education is correlated with income. High ratio will increase the demand for housing—expect positive effect.	+

Exhibit 5 | (continued)

Independent Variables

		Description and Motivation	Excepted Effect
Panel B: Municipality Attributes (continued)			
11	Average income.	Log specification. Expected positive elasticity.	+
12	Ratio of total employees to those employees living in the area.	"Commuting variable"—measures the working population during daytime relative to the working population living in the municipalities. Expected positive effect.	+
13	Ratio of net migration.*	A positive net migration is correlated with higher economic activity—pull-effect. Expected positive effect.	+
14	Ratio of age group 20–29.*	A higher ratio of this cohort should increase the demand for housing—positive demand effect.	+
15	Ratio of age group 50–64.*	Higher ratio of this cohort decreases the demand for housing—negative demand effect.	–
16	Ratio of foreign subjects.*	Non-Swedish subjects.	±
17	Ratio of votes on non-Left parties.	This ratio is highest in large and residential cities—presumably captures a wealth and income effect. Expected positive sign.	+
	K1	Large cities: Stockholm, Gothenburg and Malmö.	
	K2	Suburban municipalities.	
	K3	Large municipalities (used as a benchmark).	
	K4	Average size urban municipalities.	
	K5	Industrial municipalities.	
	K6	Rural municipalities.	
	K7	Sparsely populated municipalities.	
	K8	Other semi-large municipalities.	
	K9	Small municipalities.	

Note:
*The variable is divided by the total population in the municipalities.

contiguity weight matrices, are displayed. The results from the tested spatial autoregressive model, SEM, (with the same contiguity weight matrix specification as in the SAR model) and the SAR model, where the weight matrix is specified from different numbers of nearest neighbor are rather similar to the result presented from the chosen SAR model.[17]

There are some communities, especially those in the northern part of Sweden, that are sparsely populated rural communities covering vast areas, as compared to communities in the middle and southern part of the country. This might cause a bias in estimated parameters when spatial econometric tools are used. The number of observations from these municipalities are quite small, however, only a few percent, but whether this causes a problem was not examined.

Controlling for spatial correlations is of importance and models estimated with that spatial econometric method, having the above given reservation in mind, give a better fit. The difference between parameter estimates from OLS and the SAR model varies for certain parameters and some of these are also statistically significantly different from each other, as is indicated in Exhibit 6. This difference between the estimated models might also have an effect on the calculated constant quality price trend.

The results from the regression equations with the logarithm of the price per square meter for MDCBs as the dependent variable are reported in Exhibit 7. The sample ranges over 3 and a half years (second half of 1995 to the end of 1998) and due to missing values for both property and municipality attributes, the number of observations are reduced from 8,575 to almost 7,000 observations. When estimating the models, the full sample as well as different subsamples or sub markets are used. The three subsamples are categorized from the relative number of dwellings in the building. The following samples are used:

1. Full sample, All;
2. Buildings with more than 75% dwellings, 320;
3. Buildings with less than 75% but more than 25% dwellings, 321; and
4. Buildings with less than 25% dwellings, 325.

Later, when the estimated equations are commentated on, the codes All, 320, 321 and 325 will be used to identify the different samples.[18]

It is worth mentioning that an experiment with the logarithm of the selling prices as the dependent variable and the logarithm of the total square meters of the premises as a right-hand variable has been made, instead of using the logarithm of the square meter price. This specification considerably increased adjusted R^2—to above 90%—but the estimated parameter for the logarithm of total square meters turned out to be equal to unity; the elasticity between square meters and selling price is thus equal to one. The alternative model specification did not affect the other estimated hedonic parameters, as compared to those results reported in Exhibit 7. Accordingly, the logarithm of prices per m^2 can be used as the dependent variable in the models, without any loss of information.

Exhibit 6 | Empirical Results from Estimations of the Hedonic Model with OLS and Spatial Econometric Specifications

	320 + 321 + 325[a]				320[b]				321[c]				325			
	OLS	I	SAR	II	OLS	III	SAR	IV	OLS	V	SAR	VI	OLS	VII	SAR	VIII
Constant	4.77	9.42	3.78	13.30	4.11	6.75	3.52	7.96	5.00	4.39	3.65	3.65	7.53	5.23	5.85	49.65
2 LN(rent per m²)	0.55	20.97	0.51	37.15	0.74	17.59	0.68	27.38	0.70	10.74	0.66	19.97	0.41	12.08	0.40	15.37
3 Rents from flats to total rents	−0.13*	−9.26	−0.09	−8.55	0.10	1.80	0.08	1.53	−0.20	−5.09	−0.17	−5.02	−0.17	−2.30	−0.15	−1.85
4 Owners' relative util. of the prem.	0.06	2.06	0.04	1.54	0.20	6.48	0.18	6.72	0.00	0.03	−0.02	−0.48	−0.29	−3.29	−0.25	−2.62
5 Ratio of vacant space	−0.69	−14.73	−0.63	−17.38	−0.70	−10.95	−0.65	−15.06	−0.56	−6.16	−0.53	−6.71	−0.73	−6.08	−0.71	−6.35
6 LN(age of the building)	−0.19	−32.69	−0.19	−38.60	−0.18	−28.05	−0.18	−32.68	−0.18	−12.48	−0.19	−14.60	−0.13	−6.72	−0.14	−7.53
7 LN(distance to center)	−0.12*	−29.82	−0.09	−26.70	−0.10	−21.01	−0.08	−21.70	−0.12	−13.64	−0.10	−15.55	−0.15	−13.14	−0.14	−11.93
8 Ratio of vacant flats in the area	−0.54	−4.96	−0.36	−3.53	−0.63	−4.92	−0.48	−4.17	−0.63	−2.67	−0.52	−2.30	−0.27	−0.77	−0.15	−0.39
9 Tobin's Q	0.51*	12.28	0.30	7.48	0.50	10.07	0.30	6.38	0.53	6.36	0.34	4.26	0.50	3.22	0.35	2.50
10 Ratio higher to lower education	0.10	2.38	0.10	2.66	0.00	0.08	0.04	0.89	0.13	1.56	0.08	1.02	0.38	3.17	0.27	2.45
11 LN(average income)	0.86*	9.26	0.54	7.49	0.91	8.12	0.57	5.95	0.83	4.03	0.68	3.69	0.31	1.14	0.17	1.60
12 "Commuting" variable	0.03	1.03	0.04	1.30	0.10	2.41	0.11	3.08	−0.09	−1.50	−0.05	−0.82	0.21	1.89	0.19	1.78
13 Ratio of net migration	3.57	3.84	2.22	2.59	3.01	2.75	2.00	2.06	3.06	1.69	1.86	1.06	6.89	2.08	5.32	1.68
14 Ratio of foreign subjects	−0.52	−1.91	−0.44	−1.92	−0.56	−1.82	−0.43	−1.60	−0.25	−0.48	−0.75	−1.53	−0.09	−0.12	−0.19	−0.27
15 Ratio of age group 20–29	2.47*	5.62	1.19	3.60	2.74*	5.53	1.45	3.70	2.43	2.43	1.58	1.97	0.83	0.59	0.46	0.38

Exhibit 6 | (continued)

Empirical Results from Estimations of the Hedonic Model with OLS and Spatial Econometric Specifications

	320 + 321 + 325[a]				320[b]				321[c]				325			
	OLS	I	SAR	II	OLS	III	SAR	IV	OLS	V	SAR	VI	OLS	VII	SAR	VIII
16 Ratio of age group 50–64	−1.79	*−2.90*	−1.70	*−3.63*	−1.67	*−2.39*	−1.48	*−3.20*	−1.15	*−0.85*	−2.01	*−3.18*	−0.75	*−0.39*	−0.66	*−0.35*
17 Ratio of votes on non-Left parties	0.30	*4.61*	0.14	*2.57*	0.46*	*6.33*	0.27	*4.38*	0.19	*1.29*	0.07	*0.60*	−0.17	*−0.82*	−0.14	*−0.66*
18 Dummy 1996	0.05	*3.07*	0.04	*2.98*	0.05	*3.02*	0.04	*2.91*	0.04	*1.11*	0.05	*1.50*	0.06	*0.90*	0.07	*1.00*
19 Dummy 1997	0.16	*9.67*	0.16	*10.14*	0.16	*8.56*	0.15	*8.94*	0.14	*3.72*	0.15	*4.36*	0.19	*2.92*	0.20	*3.07*
20 Dummy 1998	0.22	*12.01*	0.22	*13.36*	0.22	*10.71*	0.22	*12.27*	0.21	*5.39*	0.24	*6.45*	0.23	*3.22*	0.24	*3.48*
21 K1	0.13	*6.17*	0.08	*4.24*	0.06	*2.22*	0.02	*1.02*	0.19	*4.79*	0.13	*3.45*	0.23	*2.98*	0.11	*1.58*
22 K2 + K5 + K7 + K9	−0.16*	*−10.93*	−0.10	*−6.98*	−0.17*	*−9.98*	−0.11	*−7.14*								
23 K4 + K6 + K8	−0.11*	*−8.56*	−0.06	*−5.04*	−0.11*	*−7.55*	−0.07	*−5.10*								
24 K4									−0.05	*−1.82*	−0.04	*−1.31*				
25 K2 + K5 + K8									−0.08	*−2.70*	−0.06	*−2.22*				
26 K7 + K9									−0.14	*−3.09*	−0.11	*−3.11*				
27 K4 + K5 + K6													−0.10	*−2.89*	−0.08	*−2.12*
28 Rho			0.34	*26.69*			0.31	*19.82*			0.30	*10.18*			0.31	*7.17*
Adj R^2	0.6639		0.7006		0.6903		0.7198		0.7120		0.7385		0.6042		0.6371	
Variance of regression	0.1088		0.0966		0.0806		0.0725		0.1166		0.1042		0.183		0.1635	

Notes: The dependent variable is the logarithm of price per m^2 for MDCBs. Asymptotic *t*-values in italics for the spatial models and White's heteroscedasticity consistent *t*-values for OLS.

*The parameters for the OLS and SAR model are significantly different from each other at the 5% level.

[a]Number of observations = 6,811.

[b]Number of observations = 4,319.

[c]Number of observations = 1,498.

Exhibit 7 | Cumulative Average Price Appreciation According to Statistic Sweden and Estimates of the Average Appreciation for Different Regions

		1996	1997	1998
	Statistics Sweden[a]	0.4	10.6	16.0
	Yearly fixed estimates (model I, Exhibit 6)	4.8	16.1	22.0
	Average appreciation for all municipalities	2.6	2.2	2.3
		1.6	1.4	1.3
K1[b]	Large cities: Stockholm, Gothenburg and Malmö	0.2	−0.4	7.8
		0.0	−0.2	5.0
K2	Suburban municipalities	5.9	7.1	12.2
		4.2	5.0	8.6
K3	Large municipalities	1.7	−0.8	−0.2
		1.2	−0.6	−0.2
K4	Average size urban municipalities	−0.3	−2.0	−3.4
		−0.3	−1.3	−2.3
K5	Industrial municipalities	1.1	2.2	2.4
		0.6	1.3	1.5
K6	Rural municipalities	2.9	1.8	5.0
		1.7	0.8	2.6
K7	Sparsely populated municipalities	−1.3	0.4	−0.7
		−0.9	0.2	−0.4
K8	Other semi-large municipalities	2.7	0.1	−1.0
		1.4	−0.3	−1.0
K9	Small municipalities	−1.5	−2.5	−3.2
		−0.9	−1.6	−2.2

Notes: Estimates based on OLS, model I, (first row) and SAR, model II, (second row).
[a] The yearly appreciation for Statistics Sweden's equally weighted index is calculated as the logarithm of the ratio between the index for the consecutive year and the value for 1995, expressed in percent. This calculation makes the appreciation rate comparable with the estimates from the hedonic models.
[b] The appreciation rates for regions K1–K9 are calculated as the sum of the product of the estimated parameter of variables 8–16, in Exhibit 6, and the absolute change in the mean value vis-à-vis the mean value for the benchmark year 1995 for these variables [see also Equation (3)].

White's residual test for heteroscedasticity for the residuals of the OLS equations in Exhibit 7 is significant for all models. This implies that usual OLS standard errors will be incorrect and for that reason, White's heteroscedasticity consistent covariance matrix estimator has been used to obtain consistent values.[19] A necessary condition for obtaining a reliable estimated parameter for the constant quality index, δ_t, is that the parameters in the model are stable. If this is not the case, a regression must be run for every year and the constant quality price must be calculated from a set of chosen values of the independent variables. An inspection of the recursive parameter estimate for the equations reveals that these seem to be rather stable over time. In none of the models could any significant change of any parameter be detected. The one-step-ahead forecast—recursive residuals—also produced acceptable results; a few residuals were found outside the error band but not in any systematic way. The models were also tested for two different sample periods: 1995–96 (2,600 observations) and 1997–98 (4,300 observations). Comparing the estimated parameters for these two periods reveals some changes in some parameters, but nothing serious. The conclusion drawn from these stability tests is that the estimated hedonic parameters are reasonably stable.[20]

The first reflection of the reported results in Exhibit 7 is that the explanatory power of the estimated models is quite high; the lowest number for adjusted R^2 is 60% and the highest is more than 70%. The spatial autocorrelation is also of importance, since the ρ-parameter in the SAR models is significant and the fit is higher for these models.

The estimated parameters for binary variables and ratio cannot in a strict sense be interpreted as relative changes. The correct number is derived by deducting the figure of 1 from the exponent of the estimated parameter, *e.g.*, $\exp(\alpha)$-1, where α is the parameter. For the sake of simplicity, however, the estimated values of the binary variables and ratios are used as they are written in Exhibit 7 in the results discussion. It is also worth mentioning that combinations of dummy variables for regions are used in the estimated models since a Wald test indicated no difference between parameters for the regions in line 22, 23, 25, 26, and 27 in Exhibit 7.

Property Attributes

The highest elasticity for the variable rent per m^2 is found for subsamples 320 and 321 in Exhibit 7. For models III and VI, this numbers is around 0.7 for the OLS specifications and slightly lower for the SAR specification. This means that a 1% change in rent changes the price of the building by some 0.7%. For subsample 325, the elasticity is even lower and ends up as 0.4. Remember that this variable, with the value of rent per m^2 from 1998, is used to control for the quality of the dwellings and the results indicate that the impact of the variable is highest in the first two subsamples.

However, from a simple and classical model for computing present value, it can be determined that the expected value for this parameter should be equal to unity.[21] The results deviate from this theoretical expected value and one explanation is due to multicollinearity between the right-hand variables. Experiments were conducted with running the models without the variables for community attributes and dummy variables for regions and the findings indicated that the elasticity for the logarithm of rent per m^2 for the full sample not was significantly different from unity; it was significantly greater than unity for subsamples 320 and 321, and less than unity for the last subsample. This might be an effect of correlation between the community attributes used and the logarithm of the rent per m^2. The community attributes are included in the hedonic model to capture demand pressure and a high demand for properties will of course also be reflected in higher rent. From this point of view it is not so strange that the estimate of the elasticity for rents deviates from unity. An other explanation to the fact that the results deviates from unity might be that a theoretical long run solution from a simple formalized model with many simplifying assumptions does not necessary hold empirically in a short run perspective.[22]

As has been argued, the system of rent control in Sweden might be important for interpreting the effect of the ratio of rents from flats to total rents. The variable is insignificant for buildings with more than 75% dwellings, 320, but significant with a negative sign for the two remaining categories and the size of the parameter differs somewhat due to econometric specification. For the later categories, this negative parameter can be interpreted as an alternative cost for using a certain area of the premises for dwellings. The estimates indicate that the price level will be −15% to −5% lower for buildings with 25% to 75% of their rents, 321, from dwellings. For subsample 325, the estimated interval ranges from −4.0% to 0%.

Owners' relative utilization of the building has no significant effect on subsample 321 but is significant with different signs for 320 and 325, and the parameter value differs somewhat, due to the econometric specification. One explanation for this change in sign might be that the price of a building mainly used for dwellings is higher, the more space the owner controls or uses. The variable might be a proxy for the degree of instant accessibility for the potential buyer; if the buyer obtains more dwellings, they can be used for purposes giving additional benefits. The negative sign for this variable for subsample 325 is trickier to explain. One possibility is that in a way, the variable captures the same effect as the ratio of vacant space; a ''veiled'' vacancy effect. When the owner of premises with less than 25% dwellings cannot let all the space in the building, the owner has to use the space.

The three remaining variables of property attributes have a straightforward interpretation. Vacant space in the premises, age of the building and distance to the (geographical) center of the municipality all have the expected effect, with some variation due to the specification. The ratio of vacant space depresses the price per m^2 most for premises in subsamples 320 and 325, while the elasticity for the age of the building is lowest for subsamples 320 and 321. Buildings with less than 25% dwellings are most sensitive to the distance from the municipally center.

Municipality Attributes

All variables for municipally attributes in Exhibit 7 are ratios, except average income. The estimated coefficients also vary due to the econometric specification.

The elasticity for this continuous income variable is significant, but less than unity, for buildings with more than 25% and insignificant for buildings with less than 25% dwellings.

All variables expressed as ratios show the expected sign that has already briefly been indicated in Exhibit 5, but not all parameters are significant for each of the three categories. The ratio of vacancies in the public housing sector significantly depresses the price for buildings with more the 25% dwellings, but is insignificant for those with less than 25% dwellings. The estimated parameter for Tobin's Q for owner-occupied houses is quite stable for all regression models. Oddly enough, the education ratio is only significant for the full sample and subsample 325. The ''commuting variable'' works for buildings with more than 75% dwellings and almost for those buildings with less than 25% dwellings, while the ratio of net immigration is significant for the same categories and the full sample.

The ratio of foreign subjects to the total population is not significant at the 5% level for any sample. The two cohorts of different age groups show the expected and significant sign for most of the categories. Finally, the ratio of votes on non-Left parties significantly inflates prices for the full sample and subsample 320.

As has been pointed out, the parameter estimates vary somewhat between the different models' econometric specifications. The estimated values for parameters for the municipality attributes from the SAR contiguity model are in general lower than those computed by OLS, except for the estimates of the yearly rate of appreciation. For the model for the full sample, for instance, the parameter estimates for Tobin's Q, income and the youngest age group for the OLS model (at the 5% level) and two more parameters (at the 10% level) are significantly different from those obtained from the SAR model. The estimates of the constant quality price index will thus depend on which model is used, since eight of the municipality attributes change values in every consecutive year.

The spatial specified regressions give a better fit than OLS and increase the coefficient of determination quite substantially in some cases. It has already been discussed that if spatial autocorrelation is present in a model, the resulting parameter estimates and confidence intervals for these parameters will be inefficient. Thus, the empirical results are an indication that using spatial econometrics when estimating hedonic price equations for MDCBs in Sweden is worthwhile, and that there is scope for further exploring this method since only used three simple standard spatial models have been used. The literature in this field is expanding rapidly so considerably more can be done.

Appreciation Rate and Regions

The dummy variables for the three years 1996, 1997 and 1998 capture the ''fixed'' part of the constant quality price appreciation as compared to 1995. The absolute change in the attribute variables (the eight variables numbered 8–15 in Exhibit 3) multiplied with its estimated parameters give the municipality effect on the appreciation rate as has also been discussed in connection with the specification of the hedonic model [see equation (3)].[23]

The fixed price appreciation is 5% between 1995 and 1996, 16% between 1995 and 1997 and 22% between 1995 and 1998 for the first two models estimated using the full sample (see also Exhibit 7). The estimated parameters for the fixed price appreciations are almost the same for subsamples 320 and 321, irrespective of the econometric specification. The estimate for subsample 325 indicates a higher appreciation for 1997 and 1998.

The parameter estimates for the municipality attributes differ for the OLS and the SAR model for certain parameters. In the first two models in Exhibit 6, the parameters for variables 3, 7, 9, 11 and 15 differ significantly from each other. The question is if this difference will affect the estimate on the constant quality price. Testing whether the sum of the parameters for the variables of pooled time series data for municipality attributes (variables 8–16 in Exhibit 6) for these two models, is equal to zero gives a t-ratio of 1.71, and a corresponding p-value, with eight degrees of freedom, of 0.125. Despite this low level of significance, the appreciation was calculated to get an idea of the difference in the estimated price trend between the two models.

The calculated average price for model I (OLS) is roughly one percentage point higher than for and model II (SAR) (see Exhibit 7). The sum of either of the estimates of the municipality and the fixed price effect gives a higher constant quality price than those compiled by Statistics Sweden.

The price appreciations for Statistics Sweden's index of MDCBs are 0.4%, 10.1% and 16.0% between 1995 and 1996, 1995 and 1997 and 1995 and 1998, respectively. These numbers are also displayed in the first row of Exhibit 7. A simple t-test also indicates that the constant quality price estimates (adding the yearly fixed estimates to the average numbers for all municipalities), using either model I or II, differ significantly from those compiled from Statistics Sweden's index.

Thus, a constant quality index based on a model for prices for MDCBs gives significantly higher estimates for the price trend than Statistics Sweden's index.[24] If the rate of appreciation for different types of municipalities is analyzed, different price trends will emerge. Exhibit 7 shows that the suburban municipalities have the highest increase followed by large cities. Even industrial and sparsely populated municipalities have a positive price trend, while all other municipalities have a negative trend. The reported result for different types of municipalities is to be expected, since a great deal of the economic activity and growth is concentrated in and around large cities and their surrounding suburbs.

When separately controlling for the geographical location of the premises with dummy variables, higher and lower levels of price per m^2 for different types of municipalities are detected. There is a clear tendency that the estimates from the SAR models display a substantially lower impact for regions than for the OLS models, and a significant difference is shown for variables 22 and 23 in Exhibit 6, for the full sample and the first subsample.

It is also clear that the estimated effect is not the same for different types of communities. Examine, for instance, the dummy for Stockholm, Gothenburg and Malmö, K1, and remember that the parameter for K1 is estimated, conditional on large municipalities, K3. For the full sample, the price level per m^2 is 13 or 8 percentage points higher, respectively, for large cities than for large municipalities. However, splitting the sample into subsamples considerably changes this estimate (see Exhibit 6). Indeed, other groups of municipalities than K1 have a lower price level than K3. For instance, the price level for submarket 320 for K4, K6 and K8 is 11 or 7 percentage points lower, respectively, than for K3 (see row 23 in Exhibit 6).[25] All reported results enhance the belief that the constant quality price level differs quite considerably between different Swedish regions.

Quarterly Appreciation Rates

The yearly fixed and non-fixed estimates for the constant quality parameters have already been displayed (Exhibit 7). As has been discussed, the fixed price effect can be estimated for higher frequencies and OLS regressions were run where quarterly dummy variables are used. The results from the experiment are shown in Exhibit 8, together with the yearly fixed estimates from Exhibits 6 and 7. Only the time dummy parameters are displayed as the other parameters in regressions I, III, V and VII did not change. This means that the share of the price appreciation for different municipalities remains unchanged, thus there is no need to report these estimates again. The adjusted R^2 for the models with quarterly dummies showed very little improvement, indicating a marginally better fit with this specification of the hedonic models. No spatial regressions with quarterly appreciation rates were run.

From Exhibit 8, it is obvious that more information is squeezed out of the data when quarterly dummy variables are used to estimate constant quality prices. Using the last two quarters of 1995 as a benchmark, constant quality prices for submarket 320 show a positive significant price trend, starting in the second quarter of 1996. The two remaining subsamples pick up a positive price trend one quarter later, but the trend drops between the second and third quarter of 1998. It is obvious that the Russian and Asian economic crisis in the second half of 1998 and its impact on the Swedish economy hit buildings with less than 75% dwellings harder than those with over 75% dwellings.

One lesson from the experiment with quarterly constant quality prices is that the price trend during the second half of 1995 to the end of 1998 is different for the three defined sub markets. The market for buildings with mainly dwellings, 320, has had an almost steady increase in constant quality price since the second half of 1996, while prices started to take off a quarter later for buildings with 25% to

Exhibit 8 | Estimated Quarterly (Q) and Yearly (Y) Constant Quality Appreciation Rates

		320+321+325 (I)		320 (III)		321 (V)		325 (VII)	
		Q	Y	Q	Y	Q	Y	Q	Y
1996	1st	0.01		0.04		−0.03		0.00	
		(0.71)		(1.86)		−(0.56)		−(0.05)	
	2nd	0.02		0.05		−0.02		−0.07	
		(1.02)		(2.58)		−(0.32)		−(0.74)	
	3rd	0.06		0.07		0.05		0.06	
		(2.86)		(2.84)		(1.05)		(0.68)	
	4th	0.09	0.05	0.05	0.05	0.11	0.04	0.25	0.06
		(4.30)	(3.07)	(2.40)	(3.02)	(2.39)	(1.11)	(2.97)	(0.90)
1997	1st	0.13		0.12		0.10		0.18	
		(6.21)		(5.27)		(2.18)		(2.03)	
	2nd	0.15		0.15		0.13		0.14	
		(7.50)		(6.98)		(2.89)		(1.70)	
	3rd	0.17		0.17		0.20		0.17	
		(7.50)		(6.82)		(3.40)		(2.06)	
	4th	0.19	0.16	0.20	0.16	0.16	0.14	0.23	0.19
		(9.62)	(9.67)	(8.75)	(8.56)	(3.54)	(3.72)	(3.06)	(2.92)
1998	1st	0.20		0.21		0.21		0.10	
		(9.16)		(8.86)		(4.41)		(1.24)	
	2nd	0.24		0.21		0.22		0.32	
		(10.22)		(8.05)		(4.67)		(4.01)	
	3rd	0.20		0.22		0.18		0.13	
		(8.42)		(8.05)		(3.78)		(1.46)	
	4th	0.24	0.22	0.26	0.22	0.19	0.21	0.19	0.23
		(10.12)	(12.01)	(9.75)	(10.71)	(3.51)	(5.39)	(2.07)	(3.22)

Note: White's heteroscedasticity consistent *t*-values in parentheses.

75% dwellings, 321. The difference between the mentioned sub markets and the market for buildings with less than 25 dwellings, 325, is obvious. All this information is veiled in my estimates for constant quality prices on a yearly basis.

Conclusion

In this paper, an elaborate hedonic price model for MDCBs in Sweden is presented. The main purpose is to estimate a constant quality price trend and, at the same time, acquire knowledge about factors determining prices for MDCBs.

Data is stratified into three sub markets, conditional on the proportion of rents from dwellings. The econometric test indicates that the explanatory powers of the models are quite high and the parameters in the hedonic equations appear to be reasonably stable. Spatial econometric techniques identified that these models improved the explanatory power and also gave lower estimates of the price trend than a corresponding model estimated with OLS.

Rent per m^2 (used as a proxy for attributes of the dwelling), the ratio of vacant space and the age of the building together with the distance to the center of the municipality are important determinants of property attributes. The proportion of rents from dwellings to total rents has a negative effect, which might be an indication of lower rent when using the premises for dwellings—an effect of rent control. Among the municipality attributes, the ratio of vacant flats, Tobin's Q for owner-occupied houses, the degree of commuting and age cohorts are worth mentioning as important variables. A high degree of significant regional differences is also detected. In addition, interest subsidies to buildings are (almost) fully capitalized.

When the constant quality price trend is estimated on a yearly basis, there are hardly any differences between the estimated parameters notwithstanding if all MDCBs are included in the sample or if the sample is split into subsamples. The reported constant quality price estimates for 1997 and 1998 are significantly higher than those that can be compiled from Statistics Sweden's index for MDCBs (Statistics Sweden's index is computed as a weighted ratio of sales prices to the assessed value of the building).

The price trend for different types of municipalities is also analyzed and the suburban municipalities are found to have the highest increases, followed by large cities. Even industrial and sparsely populated municipalities have a higher price trend than other municipalities. It is also striking that different method of estimating the models result in different estimates of the rate of appreciation. Pooled time series are used for a number of community attributes, which makes it possible to compute different price indexes for groups of municipalities. The calculated constant quality price for a model estimated with OLS is roughly one percentage point higher than for a corresponding model controlling for spatial autocorrelation.

The models used for estimating the quarterly constant quality price trend identify a statistically significant price trend for buildings with more than 75% dwellings from the third quarter of 1996. The price trend for buildings with 25% to 75% and less than 25% dwellings takes off a quarter later but drops between the second and third quarter of 1998. Naturally, the difference in the price trend between the three categories is an indication that the three sub markets react differently to the economic upswings and downturns at the end of the 1990s.

Appendix

Prices and Subsidies

One important feature of Swedish housing policy since the 1970s is the interest-subsidized loans for apartment buildings and owner-occupied houses. Long-term government guaranteed mortgage loans covering 95% to 99% of the approved building costs are granted to all new units and major renovations complying with certain government regulations on maximum and minimum standards. These subsidized loans are fully assumable by subsequent buyers of the estate. Subsidized interest rates start at very low levels and increase year by year until they reach the market rate. According to the present rules, vintages of apartment buildings built after 1980 are entitled to subsidized interest rates.

For instance, in 1989, loans to apartment buildings started at an interest rate of 2.7%, with a 0.25 percentage point yearly increase until reaching the market interest rate. The present values for the subsidies of owner-occupied houses have been computed and analyzed by Berger, Englund, Hendershott and Turner (2000). The same algorithm has been used to compile subsidies for MDCBs; calculation of the present value for the interest rate reduction for a standard housing loan, since the effects of taxes are considered. The present value of the subsidies is compiled, assuming static expectations for every period of time, that is, future tax rates and market interest rates as well as the rules for the subsidy will remain unchanged.[26]

Subsidized loans should affect the transaction price of MDCBs in a market economy. The value of buildings with subsidies (P) should exceed the value of the property without these subsidies (P'). In a perfect market, the difference between these two prices should be equal to the present value of the subsidy (S) *i.e.*, $P = P' + S$. Defining γ as the parameter indicates what fraction of the value of the subsidy is capitalized into the price. The relation between prices and the present value of the subsidy can be written as:

$$P = P'\left(1 + \frac{S}{P'}\right)^{\gamma}. \tag{A1}$$

Taking natural logs on the above equation gives:

$$\ln P = \ln P' + \gamma \ln\left(1 + \frac{S}{P'}\right). \tag{A2}$$

If the present value of the subsidy is fully reflected in the price of the property, expect γ to be a positive unity coefficient. To incorporate the effects of subsidies in the hedonic price model, Equation (A2) can be rewritten as follows:

$$\ln P' = \beta_0 + \sum_{i=1}^{m} \beta_i \ln X_i + \sum_{j=m+1}^{n} \beta_j X_j + \sum_{h=1}^{y} \delta_{t+h} D_{t+h} - \gamma \ln\left(1 + \frac{S}{P'}\right) + \varepsilon. \tag{A3}$$

Models II and IV, in Exhibit A1, have the highest fit and interest subsidies are included in these. Regressions where these subsidies are included have a dependent price variable excluding the subsidies and for that reason, the standard deviation of the dependent variable differs for the pair of models for the full sample and the subsample (the final line in Exhibit A1).[27] The estimated parameter for the subsidy variable for the different models ranges from −0.95 to −0.86. From the previous discussions, this parameter is expected to be unity with a negative sign. A Wald test indicates that, at the 5% level, the parameter differs significantly from −1 for models II and IV, while it differs insignificantly for models VI and VIII.[28] Thus, for the full sample and subsample 320, the interest rate subsidies are not fully capitalized from a statistical point of view. But the estimates are very close to −1, so it is no exaggeration to say that subsidies are almost fully capitalized. The results are consistent with those reported by Hendershott and Turner (1999) who used a sample of 422 observations for properties in Stockholm from the beginning of the 1990s.[29] If the models pair-by-pair for the full sample and the three subsamples are compared, the estimated parameter for all other variables are very stable and identical except in one or two cases. If there is a difference between the parameters, they are probably not significant.

An alternative iterative approach for estimating the effect of interest-subsidies has also been used. The test was set up with a modified version of Equation (A3)

$$\ln P' + \gamma \ln\left(1 + \frac{S}{P'}\right) = \beta_0 + \sum_{i=1}^{m} \beta_i \ln X_i + \sum_{j=m+1}^{n} \beta_j X_j + \sum_{h=1}^{y} \delta_{t+h} D_{t+h} + \varepsilon. \tag{A4}$$

Equation (A4) is conditionally estimated on the γ-parameter. The highest log-likelihood and R^2 were found for γ-parameters with numbers almost identical to those reported in Exhibit A1.

Exhibit A1 | Empirical Results from Estimation of the Hedonic Model

		320 + 321 + 325		320		321		325	
		I	II	III	IV	V	VI	VII	VIII
1	Constant	4.84	4.76	4.25	4.11	5.08	5.17	7.39	7.35
		(9.73)	(9.46)	(7.13)	(6.79)	(4.53)	(4.61)	(5.13)	(5.08)
2	LN(rent per m^2)	0.56	0.55	0.74	0.73	0.71	0.71	0.40	0.40
		(20.48)	(20.22)	(17.90)	(16.84)	(10.78)	(10.79)	(11.91)	(11.90)
3	Rents from flats to total rents	−0.14	−0.14	0.09	0.09	−0.20	−0.20	−0.16	−0.16
		(−9.68)	(−9.74)	(1.63)	(1.67)	(−4.99)	(−5.04)	(−2.11)	(−2.13)
4	Owners' relative utilization of the premises	0.07	0.07	0.20	0.20	0.01	0.01	−0.29	−0.29
		(2.45)	(2.42)	(6.56)	(6.51)	(0.10)	(0.10)	(−3.25)	(−3.24)
5	Rent of vacant space	−0.69	−0.70	−0.70	−0.72	−0.55	−0.55	−0.72	−0.72
		(−14.70)	(−14.52)	(−11.15)	(−10.90)	(−6.11)	(−6.15)	(−6.07)	(−6.05)
6	LN(age of building)	0.19	−0.19	−0.18	−0.18	−0.18	−0.18	−0.13	−0.13
		(−33.18)	(−29.55)	(−28.62)	(−25.42)	(−12.42)	(−11.82)	(−6.67)	(−6.56)
7	LN(distance to CBD)	−0.12	−0.12	−0.10	−0.10	−0.12	−0.12	−0.15	−0.15
		(−29.82)	(−29.51)	(−21.31)	(−20.75)	(−13.78)	(−13.82)	(−12.99)	(−12.95)
8	Ratio of higher to lower education	−0.57	−0.58	−0.62	−0.63	−0.69	−0.69	−0.31	−0.30
		(−5.35)	(−5.35)	(−4.96)	(−4.98)	(−2.90)	(−2.90)	(−0.86)	(−0.85)
9	LN(average income)	0.51	0.52	0.48	0.49	0.52	0.52	0.50	0.50
		(12.45)	(12.38)	(10.12)	(9.92)	(6.45)	(6.41)	(3.22)	(3.23)
10	Ratio of higher to lower education	0.10	0.09	0.02	0.01	0.15	0.15	0.39	0.39
		(2.54)	(2.30)	(0.47)	(0.14)	(1.71)	(1.78)	(3.20)	(3.18)
11	LN(average income)	0.83	0.84	0.88	0.89	0.81	0.79	0.33	0.34
		(9.15)	(9.15)	(8.07)	(8.05)	(3.99)	(3.89)	(1.22)	(1.23)

Exhibit A1 | (continued)

Empirical Results from Estimation of the Hedonic Model

	320 + 321 + 325		320		321		325	
	I	II	III	IV	V	VI	VII	VIII
12 Ratio of total employees to those employees living in the area	0.04	0.04	0.10	0.10	−0.08	−0.08	0.24	0.24
	(1.36)	(1.32)	(2.42)	(2.41)	(−1.37)	(−1.36)	(2.16)	(2.15)
13 Ratio of net migration	3.29	3.29	2.79	2.76	2.54	2.51	6.22	6.16
	(3.70)	(3.66)	(2.69)	(2.63)	(1.41)	(1.40)	(1.98)	(1.96)
14 Ratio of foreign subjects	−0.56	−0.59	−0.56	−0.61	−0.32	−0.29	−0.07	−0.10
	(−2.09)	(−2.19)	(−1.84)	(−2.00)	(−0.61)	(−0.56)	(−0.09)	(−0.13)
15 Ratio of age group 20–29	2.60	2.71	2.81	3.00	2.37	2.30	0.74	0.78
	(6.03)	(6.25)	(5.82)	(6.15)	(2.40)	(2.33)	(0.52)	(0.55)
16 Ratio of age group 50–64	−1.50	−1.44	−1.48	−1.45	−0.96	−0.88	−0.64	−0.63
	(−2.49)	(−2.38)	(−2.18)	(−2.11)	(−0.73)	(0.67)	(−0.34)	(−0.33)
17 Ratio of votes on non-Left parties	0.31	0.32	0.47	0.50	0.20	0.22	−0.20	−0.20
	(4.83)	(4.97)	(6.53)	(6.80)	(1.37)	(1.48)	(−0.96)	(−0.96)
18 Dummy 1996	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.05
	(3.11)	(2.95)	(3.21)	(3.03)	(1.26)	(1.13)	(0.71)	(0.70)
19 Dummy 1997	0.16	0.16	0.16	0.16	0.15	0.14	0.18	0.18
	(9.84)	(9.76)	(8.95)	(8.89)	(3.85)	(3.73)	(2.66)	(2.63)
20 Dummy 1998	0.22	0.22	0.22	0.23	0.22	0.22	0.21	0.21
	(12.26)	(12.22)	(11.14)	(11.18)	(5.57)	(5.47)	(2.96)	(2.94)
21 K1	0.13	0.13	0.06	0.07	0.19	0.19	0.23	0.23
	(6.37)	(6.51)	(2.49)	(2.72)	(4.71)	(4.73)	(2.98)	(2.99)

Exhibit A1 | (continued)

Empirical Results from Estimation of the Hedonic Model

		320 + 321 + 325		320		321		325	
		I	II	III	IV	V	VI	VII	VIII
22	K2 + K5 + K7 + K9	−0.16	−0.16	−0.17	−0.17				
		(10.98)	(−10.88)	(−10.04)	(−9.78)				
23	K4 + K6 + K8	−0.11	−0.11	−0.10	−0.10				
		(−8.84)	(−8.76)	(−7.52)	(−7.29)				
24	K4					−0.06	−0.06		
						(−2.08)	(−2.04)		
25	K2 + K5 + K8					−0.09	−0.09		
						(−2.93)	(−2.94)		
26	K7 + K9					−0.14	−0.15		
						(−3.24)	(−3.32)		
27	K4 + K5 + K6							−0.12	−0.12
								(−3.18)	(−3.18)
28	LN(1 + S/P′)		−0.95		−0.97		−0.90		−0.86
			(68.79)		(−75.06)		(−15.41)		(−6.46)
	Adj. R^2	0.6661	0.7402	0.6910	0.7958	0.7102	0.7191	0.6018	0.6015

Notes: The dependent variable is the logarithm of square meter price with subsidies included (model I) and deducted (model II). White heteroscedasticity consistent *t*-values in parentheses. Number of observations: model I = 6,940; model II = 6,853; model III = 4, 511; model IV = 4,425; model V = 1,1441; model VI = 1,550; model VII = 878; and model VIII = 878.

The conclusion of this analysis is that subsidies are (almost) fully capitalized and the parameters in the model remain unchanged, regardless of how the models are specified. This also means models were developed with or without subsidies. In the main text, models were used that included interest rate subsidies in the right-hand variable.

Endnotes

[1] For surveys of techniques used in estimating house prices see, for instance, the *Journal of Housing Research*, (1995, volume 6, issue 3) and the *Journal of Real Estate Finance and Economics* (1995, volume 17, issue 10).

[2] It can be noted that the Swedish Riksbank uses Celexa Aberdeen's price indexes for commercial real estate in their appraisal of tendencies in the financial system and their implications for stability (see Financial Stability Report 2001; and Sveriges Riksbank, May 2001).

[3] Clapp and Giaccotto (1992) have also shown the effect of error in the measurement of assessed values on price indexes to be negligible when the change in the composition of the sample is small.

[4] For studies using the hedonic technique, see Berger (1998) and Wigren (1986). Englund, Quigley and Redfearn (1998, 1999) used the hybrid approach in their study.

[5] See Turner (2001).

[6] The Ministry of Finance, the National Tax Board and the National Land Survey of Sweden implement property taxation in Sweden. The National Tax Board is the body with the main responsibility for the administration of property taxes. The National Land Survey of Sweden builds and updates the valuation models determining the assessment values. For this purpose, they use data from the cadastral survey and surveys of the General and Special Assessment of Real Estate.

[7] The index is constructed as a weighted average with the assessed value as the weight and can be written as $\Sigma(\mathrm{Vit}/\Sigma\mathrm{Vit})(\mathrm{Pit}/\mathrm{Vit}) = \Sigma\mathrm{Pit}/\Sigma\mathrm{Vit}$, where Pit and Vit correspond to the price and assessed value of the *i*th house sold in time period *t*. Since 1981, the assessment value for MDCBs has been recalculated twice. The recalculation normally causes shifts in the price trend, but Statistic Sweden has compiled a comparable time series.

[8] Catella Property Management, Stockholm, compiles the index. The Catella index is a simple price index based on the mean prices and does not consider the characteristics or qualities of the buildings.

[9] The modified J test that Green (1997) has labeled the PE test is used. This test can be used to test different functional specifications against each other. The log-linear model has been tested against linear, semi-log and square root specifications and the results of these rejected the two latest specifications. The linear model could not be rejected with the PE test. An additional test was run with Box-Cox transformation. It was set up with two alternative models, which are both modified forms of Equation (2): $(P^{\lambda} - 1)/\lambda = \beta_0 + \sum_{i=1}^{m} \beta_i (X_i^{\lambda} - 1)/\lambda + \ldots.$ and $\ln P = \beta_0 + \sum_{i=1}^{m} \beta_i (X_i^{\lambda} - 1)/\lambda + \ldots$, where λ is a free parameter. The models have then been estimated conditional on λ. The highest log-likelihood and R^2 were found for values of λ close to zero for both models. It can be

shown that if $\lambda = 0$, then $(P^{\lambda} - 1)/\lambda \approx \ln P$ and $(X^{\lambda} - 1)/\lambda \approx \ln X$. Thus, the test favors the log-linear specification. The results of the tests are available from the author upon request. The software used is EVIEWS.

[10] For a good introduction to the area of spatial econometrics and modeling see *i.e.*, the *Journal of Real Estate Finance and Economics* (1998, Volume 17, issue 1) and LeSage (2001).

[11] It is easy to translate the symbols of Equation (4) into those used in Equation (2). y is a vector of the logarithm of price per m^2 and $X\beta$ is a matrix containing the parameters.

[12] The weight matrix, based on the Delaunay triangularization scheme, partitions the space into triangles such that there are no observations in the interior of any triangle and neighbors are then defined as observations on the same triangle.

[13] Data is collected from the survey of the year 2000 for the General and Special Assessment of Real Estate.

[14] For details on the Swedish system of rent control, see Turner (1988).

[15] The classification made by the Swedish Association of Local Authorities is used for different types of municipalities. The regrouping used for descriptive purposes is the following: large cities (Stockholm, Gothenburg and Malmö), K1; large municipalities, K3; suburban, industrial, sparsely populated and small municipalities, K2+K5+K7+K9; and average size urban, rural and other semi-large municipalities, K4+K6+K8.

[16] Tommy Berger has supplied the present value estimates for the interest-rate subsidies. This has made it possible to compile the price per m^2 for MDCBs excluding subsidies, which is used in the empirical test in the Appendix. He has also supplied estimates of Tobin's Q (ratio between the market price and the replacement value of an asset) for owner-occupied houses. Lena Magnusson has compiled data for longitude and latitude for the center of the 289 municipalities. Combining the spatial coordinates for the municipalities and the properties sold makes it possible to calculate the distance from the center of the municipality. Most of the municipality attribute variables have been collected from Sweden's Statistical Databases on the Internet. The database is run by Statistic Sweden (www.scb.se).

[17] The results from the tests discussed are available from the author upon request.

[18] The software used for the estimated models in Exhibit 7 is EVIEWS and LeSage (1999) spatial econometrics library for MATLAB.

[19] This method provides more correct estimates of the coefficient covariances in the presence of heteroscedasticity of unknown form. If the heteroscedasticity in the residual is of a known form, the remedy is weighted least squares. If it is of an unknown form, White's heteroscedasticity consistent covariance matrix and the generalized method of moment (GMM) can be used.

[20] The results from the tests discussed are available from the author upon request.

[21] The classical Gordon's growth formula helps with the intuition behind this statement. Assuming constant rents and constant risk adjusted return for the building from now to eternity then the price of the building (P) will be equal to the ratio between the rent (H) and risk-adjusted return (R). After taking logs on Gordon's formula, the equation can be written as $\ln P = \ln H - \ln R$. The derivative on $\ln P$ with respect to $\ln H$ is thus equal to unity—the elasticity of the price with respect to rent is unity.

[22] An alternative approach could be to put restrictions on the elasticity for the logarithm of rent per m^2 to be equal to unity. This would mean that we should have the logarithm

of the cap rate as dependent variable, $\ln(P/H)$, in the model but this issue is left for future research.

[23] For the sake of simplicity, the estimated values of the yearly dummy variables and the sum of the effect from the municipality attributes are used as the relative change in constant quality price compared to 1995, expressed as percent. This is an approximation, since the "true" estimated relative change is $\exp(\alpha) - 1$.

[24] The estimated numbers can also be seen as the real rate of constant quality price appreciation, since the rate of inflation in Sweden was almost non-existent in these years; it amounted to 0.5%, 0.5% and −0.1%, respectively.

[25] As said earlier, combinations of dummy variables are employed for regions in the estimated models since a Wald test indicated no difference between parameters for the regions in line 22, 23, 25, 26 and 27 Exhibit 7.

[26] For details, see Berger, Englund, Hendershott and Turner (2000).

[27] On average, 9% of the buildings have interest subsidies. For the three subsamples, this figure was 12.5%, 5.2% and 1.1%, respectively.

[28] The prob-value for the Wald test is 0.00, 0.01, 0.07 and 0.28, respectively.

[29] The model Hendershott and Turner (1999) used was specified without community attribute variables. Berger, Englund, Hendershott and Turner (2000) report the unity capitalization coefficient for owner-occupied houses in Sweden.

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